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Dietary Inclusion of Triticale and Bentonite Enhances Productive Performance and Carcass Meat Characteristics of Broiler Chickens

Belhocine Chaima[1], Belabbes Mohamed[1], Bouderoua Kaddour[2], Larbaoui Abdelkarim[2], Chaib Eddour Ahmed Readh[1]

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ABSTRACT

Background: Poultry production quality could be adjusted or improved through the introduction of local plant resources into the diet. The current study evaluated the effects of total corn substitution with triticale and bentonite supplementation on broiler performance, carcass meat characteristics and blood profiles.

Methods: Ninety one-day old broiler Cobb 500 chicks were allocated in a completely randomized experimental design, with three dietary treatments totaling 30 birds per treatment. The treatments contained either corn as a control group (BD), triticale (TRT) as a sole grain source, or triticale + 2% bentonite (TRT2%). The diets were provided from 14 to 47 days of age. Growth performance, carcass and breast meat quality and serum components were measured.

Result: The chicks fed a triticale-based diet (TRT2%) had a higher final body weight and weight gain ($P<0.05$), while the FCR increased in the birds fed a triticale-bentonite-based diet (TRT2%). The data obtained indicated that total replacement of triticale for corn and dietary supplementation with bentonite resulted in better growth performance and an increase in breast yield ($P<0.05$). Moreover, the dietary supplementation of bentonite and triticale had a significant influence ($P< 0.05$) on the serum levels of triglycerides and calcium. The chicks fed a basal diet had significantly ($P<0.05$) higher triglycerides and lower calcium blood serum levels than those fed experimental diets. However, there was no significant effect on breast meat traits ($P>0.05$).

Key words: Bentonite, Blood profiles, Broiler chicken, Carcass traits, Meat quality, Triticale.

INTRODUCTION

An upward trend in meat consumption induced an increased demand for feedstuffs. One of the ongoing challenges in poultry production is the increasing price of feed. Corn is a fundamental ingredient in the diet and the mainstay of energy in the poultry industry. It serves as food and feed; indeed, the prices of corn are currently increasing; thus, it recorded an average increase of 90% in one year, according to the FAO, 2021. Several countries resort to importing corn for the production of chicken meat (Bada *et al.,* 2022; Moez *et al.,* 2020). Given this background, it is necessary to find locally available, economical and nutritionally suitable alternatives for corn in poultry feeding. One approach seems to be applying unconventional types of grain in chicken diets as suppliers of protein and energy (triticale) and mineral nutrition (bentonite).

Triticale is typically used as feed for livestock owing to its elevated total protein and carbohydrate contents. It has a higher crude protein and lysine level than corn (11% vs. 8%) and (0.37% vs. 0.26%), respectively (Sullivan *et al.*, 2007). Triticale is a hybrid cereal obtained by crossbreeding wheat and rye (Abdelaal *et al.*, 2019). Several research studies suggest that triticale may effectively substitute corn in animal diets without having an adverse effect on animal welfare (Dekic *et al.*, 2015; Zarghi *et al.*, 2010).

The current situation also requires the introduction of nonnutritive feed additives, such as aluminosilicate minerals, to reduce production costs while improving nutritional efficiency (Safaeikatouli *et al.*, 2012). Clay minerals such as bentonite have been widely used in poultry feeding. Numerous research investigations have discovered that adding silicate minerals to livestock diets promotes body weight gain and feed conversion ratio (Fethia *et al.*, 2023; Banaszak *et al.*, 2020; Chen *et al.*, 2020; Prvulovic *et al.*, 2008).

[1]Laboratory of Biotechnology Applied to Agriculture and Environmental Preservation in Higher School of Agronomy "Mohamed El Amjed Ben Abdel Malek", Hall Technology Kharouba, Mostaganem- Algeria.

[2]Laboratory Food Technology and Nutrition, University of Mostaganem "Abdelhamid Ibn Badis", Mostaganem-2700, Algeria.

Corresponding Author: Belhocine Chaima, Laboratory of Biotechnology Applied to Agriculture and Environmental Preservation in Higher School of Agronomy "Mohamed El Amjed Ben Abdel Malek", Hall Technology Kharouba, Mostaganem- Algeria. Email: c.belhocine@esa-mosta.dz

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Overall poultry production quality could be improved through the introduction of local inputs into the diet. Thus, the use of triticale as a nutrient piqued the interest of scientists, who carried out several studies as well as many investigations about clay mineral dietary supplementation. Additional research will be necessary to assess the impact of their use in broiler diets. Therefore, the present study was designed to determine the effect of the total replacement of triticale for corn and the dietary inclusion of bentonite on the production performance, carcass meat characteristics and blood profile of chicken broilers.

MATERIALS AND METHODS

Feeding experimental design

Ninety one-day-old male Cobb 500 broiler chickens with an initial BW of 45 g procured from a commercial hatchery were used in the experiment. The birds were fed a balanced commercial starter diet for two weeks. On day 14, they were weighed individually (average BW±450 g) and randomly distributed into three dietary treatment groups (30 birds per group). The three dietary treatments were the following: birds received basal diet (BD) corn-soybean meal diet; in the two other trial groups, triticale totally (100%) replaced corn (TRT) and then supplemented with 2% bentonite (TRT 2%) in the third group. The bentonite was acquired from the western region of Algeria by the National Company for Non-ferrous Mining Products, ENOF, while the triticale seeds were obtained from a local crop producer in the western region of Algeria (Mendes, Relizane, Algeria). In this experiment, Birds were reared under standard rearing conditions with a litter floor system and were provided with 23 hours of light and 1 hour of darkness during the first 21 days of rearing, followed by 22 hours of light and 2 hours of darkness (from the 22nd to the 47th day of rearing). The experimental room temperature initially was set at 38°C, gradually reduced by 3°C every week until it reached 22°C. The trial was carried out during March and April 2022 at the Higher School of Agronomy "Mohamed El Amjed Ben Abdel Malek" in Mostaganem, Algeria. All husbandry protocols and slaughtering were carried out with full regard for animal welfare.

Nutrient composition

The chemical composition of the basal diet and experimental feed is presented in (Table 1). Samples of triticale seeds were analyzed in duplicate for dry matter and ash (Afnor, 1985), crude protein (AOAC, 2005), crude fat (AOAC, 2006) and crude fiber (AOAC, 2005) (Table 2).

Body weight, weight gain and feed conversion ratio measurements

On a weekly basis, broilers were individually weighed and the weight gain of each group had been calculated. The FCR was also calculated and expressed throughout the grower and finisher periods.

Blood biochemical profile measurements

On the 46th day, five blood samples were taken from birds in each pen for blood chemical analysis. After the transfer of blood samples onto ice, they were centrifuged at 1500 g for 10 min in the laboratory. The serum was properly collected and stored at -20$^{238}_{92}$C until analysis. The serum total protein,

Table 1: The composition of the basal and experimental diets.

Ingredients (%)	Basal diet	TRT	TRT2%
Corn	67.00	0	0
Soybean meal	27.00	27.00	27.00
Triticale	0	67.00	67.00
Wheat bran	4.00	4.00	2.00
Bentonite	0	0	2.00
Vitamin-mineral premix*	1.00	1.00	1.00
Calcium	0.50	0.50	0.50
Phosphorus	0.50	0.50	0.50
Calculated composition			
Metabolisable energy (Kcal/kg)	3045.65	2888.40	2854.10
Methionine (%)	0.46	0.49	0.48
Cysteine (%)	0.51	0.59	0.58
Methionine + cysteine (%)	1.01	1.12	1.10
Analyzed composition (%)			
Crude protein	19.59	20.39	20.09
Crude fat	5.28	2.74	2.53
Crude fiber	3.85	2.00	2.25
Dry matter	87.97	89.65	90.46
Ash	5.10	5.47	5.95

*Vitamin-mineral premix provide the following quantities per kilogram of diet: Vitamin E: 6, Vitamin K3: 0.80, Vitamin B2: 3, Vitamin B6: 1.5, Iode: 0.8, Magnesium: 100; TRT: Triticale totally replaced corn; TRT2%: Triticale totally replaced corn + 2% of bentonite.

triglyceride, cholesterol total and calcium concentrations were measured in a spectrophotometer using laboratory kits provided by BIOLABO SAS, France.

Carcass meat characteristics

At the end of the experiment (47 days of age), 7 birds from each treatment group were selected, individually weighed and manually slaughtered to evaluate carcass and meat characteristics. After evisceration, carcass, liver, abdominal fat and breast and thigh muscle were weighed individually and their percentage based on carcass eviscerated weight was calculated. Breast meat samples have been retrieved from each carcass to evaluate meat quality. The ultimate pH of the samples was measured after 24 hours of slaughter by inserting a 2.5 cm dagger electrode under the surface of the breast muscle using a pH meter (WTW™ inolab 7310, France). Chemical analysis of the meat (dry matter, crude ash) was determined using conventional methods (Afnor, 1985).

Statistical analysis

The results are presented as mean values and the standard error of the means (SEM). All the data had been statistically analyzed using the one-way analysis of variance (ANOVA) method and IBM SPSS statistical software (version 26). Mean differences were compared using Tukey's test. The difference was considered significant when the $P<0.05$.

RESULTS AND DISCUSSION

Growth performance

Table 3 illustrates the average weekly BW and WG of birds in different treatment groups. The trial began with no difference among treatments ($P>0.05$). Chickens given a diet supplemented with bentonite had a higher BW from the 14th to the 41st days of age ($P<0.05$). However, the chicks fed a triticale-based diet had a growth peak at the 34th and 41st days, with a weight gain of 599.50 and 602 g, respectively, to reach the highest final weight of 2868 g ($P<0.05$). Additionally, the diet type influenced significantly ($P<0.05$) the FCR throughout the feeding period. In the grower period, it was highest in the basal diet, while in the finisher period, it increased in the birds fed experimental diets.

The current findings contrasted with those reported in previous studies, which found a negative effect of the

Table 2: Analyzed Chemical composition of triticale grains.

Contents (%)	Triticale
Dry matter	89.9
Ash	1.8
Crude fiber	4.1
Crude fat	1.54
Crude proteins	11.1

For each value, n= 7.

Table 3: Effect of dietary inclusion of triticale and bentonite on the average weekly body weight (g), weight gain and FCR of broiler chickens.

Parameters	Days				
	Grower period (14-34th day)			Finisher period (35-47th day)	
	14-20	21-27	28-34	35-41	41-47
Body weight (g)					
Basal diet	782.00	1135.50^{a}	1645.50^{a}	2222.50^{a}	2689.50^{a}
TRT	793.00	1171.00^{a}	1770.50^{b}	2373.00^{b}	2868.50^{b}
TRT2%	803.50	1250.80^{b}	1830.00^{b}	2420.50^{b}	2759.00^{a,b}
SEM	4.89	11.52	20.12	26.82	26.81
P value	0.000	0.000	0.000	0.004	0.017
Weight gain (g)					
Basal diet	322.50	353.50^{a}	510.00^{a}	577.00	467.00^{b}
TRT	341.00	378.00^{a}	599.50^{b}	602.00	495.50^{b}
TRT2%	353.50	447.30^{b}	579.50^{b}	590.50	338.50^{a}
SEM	6.30	11.27	11.13	9.07	15.11
P value	0.204	0.000	0.001	0.547	0.000
FCR					
Basal diet		1.70^{b}		2.17^{a}	
TRT		1.55^{a}		2.38^{a}	
TRT2%		1.52^{a}		2.83^{b}	
SEM		0.02		0.05	
P value		0.000		0.000	

^{a,b}Means with different superscripts in each row differ significantly ($P<0.05$). For each group (n= 10).

SEM: Standard error of means. FCR: Feed conversion ratio. TRT: Triticale totally replaced corn.

TRT2%: Triticale totally replaced corn and supplemented with 2% of bentonite.

inclusion of triticale on performance characteristics (Baser and Yetisir, 2014; Korver *et al*., 2004). Remarkably, in our investigation, the performance improved by 3%. This might be attributed to the bentonite and triticale combination, which mitigated the adverse effects of triticale. Similarly, using 40% triticale in diets had no deleterious effects on broiler performance (Zarghi and Golian, 2009). In another trial by Zarghi *et al*. (2010), FCR raised as much as the triticale level, supporting our findings of increased FCR.

In the current experiment, the improvement might be attributed to the effect of bentonite on gastrointestinal tract health, which promotes nutrient digestibility, along with the triticale seed content of essential amino acids, certain minerals and vitamins, which might satisfy a considerable part of the demands of animals (Glamoclija *et al*., 2018; Yan *et al*., 2011). Similar to our findings, adding modest doses of bentonite (<2%) offers a more desired result (Mahesh and Lohan, 2008; Pasha *et al.,* 2008). Furthermore, several scientists have indicated that clays have no damaging effect on performances (Indresh *et al*., 2013; Safaei *et al*., 2010). Similarly, increased FCR was observed in chicks given diets supplemented with bentonite (Bouderoua *et al*., 2016; Pasha *et al*., 2008; Tauqir and Nawaz, 2001).

Blood parameters

The blood parameters of all experimental chicks are tabulated in (Table 4). The supplementation of bentonite and triticale had no significant influence (P>0.05) on the blood serum concentrations of total protein and cholesterol. Serum concentrations of triglycerides were significantly higher (P<0.05) in the blood samples from animals fed a standard diet. Although the chicks fed experimental diets had significantly higher (P<0.05) calcium blood serum levels than those fed the basal diet.

The results aforementioned are compatible with the results of (Shannon *et al*., 2017; Bouderoua *et al*., 2016), who found that bentonite administration had no effect on serum concentrations of total protein (P>0.05). According to Zarghi and Golian, (2009), the substitution of corn by triticale at different levels had no effect on the level of serum cholesterol, although higher levels of triticale substitution quantitatively decreased the cholesterol blood concentration, as observed in the present trial. Similarly, silicate mineral supplementation experienced no influence on the concentration of cholesterol in the blood serum (Uzunoglu and Yalcin, 2019; Eleroglu *et al*., 2011; Prvulovic *et al*., 2008). The variation in the level of serum cholesterol may be associated with the possibility that nanoparticle-sized particles of different minerals in clay improve the biodisponibility of nutrients and increase their absorption, contributing to the enhanced general performance of broiler chicks, particularly blood biochemicals, as suggested by Al-beitawi *et al*. (2017). As explained by (Zarghi *et al*., 2010), the viscosity-forming properties of soluble dietary fibers, such as b-glucans present in triticale grains, could reduce the absorption of cholesterol and its properties.

Our observations share similarities with previous studies, which noted that broiler chicks feeding bentonite had significantly higher plasma calcium concentrations than the control group (Bouderoua *et al*., 2016; Safaeikatouli *et al*., 2012). Inconsistent results were shown by Eraslan *et al*. (2005), who found that the serum concentration of calcium was reduced in birds receiving bentonite compared to the control group, which contradicts our findings.

Carcass and meat quality traits

The results of carcass meat features and relative organ weights are shown in (Table 5). The statistical analysis of the data indicated that there were no significant differences (P>0.05) in eviscerated weight, dressing percentage, or thigh percentage across the three treatment groups. However, there were high significant differences (P<0.05) in breast and abdominal fat yields; the relative weights of breast increased while the relative AAT weight decreased in the experimental diets compared to the control one. The liver weight was significantly affected (P<0.05) by the inclusion of triticale and bentonite in the diet. On the flip side, it had no significant effect on meat pH 24 hours after slaughter or ash content, except for meat dry matter, which increased significantly with the bentonite supplementation (P<0.05).

According to (Zarghi *et al*., 2010), there were no significant differences in the carcass weight of the chicks given degraded levels of triticale substituted for corn. Furthermore, the introduction of whole triticale grains in poultry diets ranging from 15% to 25% ameliorated the

Table 4: Effect of dietary inclusion of triticale and bentonite on blood profiles.

Parameters	Triglyceride (g/L)	Totalcholesterol (g/L)	Total protein (mg/dl)	Calcium (mg/dl)
BD	0.74[a]	1.46	49.28	11.99[a]
TRT	0.58[a,b]	1.21	49.58	14.7[b]
TRT2%	0.61[b]	1.34	47.08	15.51[b]
SEM	0.02	0.09	0.74	0.44
P value	0.041	0.611	0.352	0.000

[a,b] Means with different superscripts in each row differ significantly (P<0.05). For each group (n= 5).

SEM: Standard error of means. BD: Basal diet. TRT: Triticale totally replaced corn;

TRT2%: Triticale totally replaced corn +2% of bentonite.

Table 5: Effect of dietary inclusion of triticale and bentonite on carcass parameters, organ relative weight and breast meat traits of broiler chickens at 47 days of age.

Items	Treatments				
	Basal diet	TRT	TRT2%	SEM	P value
EW (g)	2047.14	2136.43	2023.29	21.42	0.068
Dressing (%)	85.59	86.85	87.76	0.94	0.666
Thigh (%)	13.99	13.57	14.24	0.27	0.62
Breast (%)	34.30^{a}	35.55^{a,b}	38.00^{b}	0.58	0.022
Liver (g)	50.96^{a,b}	55.76^{b}	49.12^{a}	0.98	0.009
AAT (%)	1.67	0.75	0.48	0.14	0.000
Breast meat traits					
pH_{24h}	5.71	5.60	5.71	0.02	0.503
Dry matter (%)	27.00^{a}	25.09^{a}	27.62^{b}	0.37	0.004
Crude ash (%)	2.54	1.17	1.11	0.16	0.458

^{a,b}Means with different superscripts in each row differ significantly (P<0.05). For each group (n= 7).
SEM: Standard error of means. EW: Eviscerated weight. AAT %: Relative weight of abdominal adipose tissue.
TRT: Triticale totally replaced corn. TRT2%: Triticale totally replaced corn +2% of bentonite.

balanced amino acid composition, which promotes muscular development with 4% and 10% amelioration in breast muscle yield from the TRT and TRT2% diets, respectively, in the current study.

In our research, the addition of bentonite improved the eviscerated carcass and thigh weights. Comparable results were obtained in the trial conducted by Bouderoua *et al*. (2016). Added to that, using silicate minerals in the diets of broilers might increase nutritional digestibility and shorten the gastrointestinal transit rate, extending the time of digestion of nutrients (Safaeikatouli *et al*., 2012). As indicated in the present study, it is interesting to emphasize that the relative weight of abdominal adipose tissue was significantly decreased in experimental diets, which is in accordance with the findings of Baser and Yetisir, (2014), who found that the use of triticale reduced abdominal fat yield when contrasted with corn diets.

Interestingly, liver weight decreased significantly (P<0.05) when triticale and bentonite were included in the diet, which may be explained by the presence of higher non-starch polysaccharides in triticale compared to corn, which could increase the viscosity of the intestinal digest and result in an improvement of the activities of the intestinal secretory mechanisms. As a consequence, the size of the gastro-intestinal tract and liver might increase (Wang *et al*., 2005). Recently, Banaszak *et al*. (2020) indicated that it is possible that the inclusion of halloysite changes the size of the liver, which affects both the availability of nutrients and the detoxification function.

In the current study, feeding triticale and bentonite to broilers significantly improved the relative weight of breast muscles and had no significant effect on breast meat traits except for the water content, which increased with the addition of 2% bentonite. As reported by Gheorghe *et al*. (2022), partial corn replacement by triticale in broilers diet had no significant effects on breast muscle pH 24 h. Similarly, differences in water content in breast muscles were found between the control and experimental groups (Banaszak *et al*., 2020).

As stated by Nadziakiewicz *et al*. (2023), the pH24 measurements for breast meat in the control and halloysite treatment groups varied from 5.93 to 5.83, allowing this meat to be classified as normal. The findings are consistent with prior research, which has indicated that the addition of silicate minerals to a broiler chicken's feed has no influence on the pH24 level of their breast muscles (Prvulovic *et al*., 2008).

CONCLUSION

The data obtained indicated that total replacement of triticale for corn and dietary supplementation with bentonite resulted in better growth performance and an increase in breast yield. The results of the above research might prove helpful to feed producers and poultry farmers, seeing as local triticale seeds and bentonite can be successfully added to the diet to improve feed efficiency and enhance slaughter weight.

Conflict of interest

On behalf of all authors of this manuscript, we declare that there are no conflicts of interest related to this work. We have no financial or personal relationships with individuals or organizations that could have inappropriately influenced the research presented in this paper.

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